12 BIODIVERSITY

Earlier in this report, the extent and condition of certain organism groups (fish, benthic macroinvertebrates, etc.) were presented under the headings of Characterization (Chapter 4) and Biological Assessment (Chapter 5). While these results do a good job of describing the general quality of Maryland's nontidal streams, they do not capture the full variety of aquatic biota in the State, i.e., its biodiversity. Specifically, although the concept of biological integrity (as embodied in the Index of Biotic Integrity (IBI) results of Chapter 5) attempts to capture the central premise of biodiversity (i.e., the natural state of biological communities), use of the IBI alone cannot describe or preserve all components (e.g., rare species and unusual ecosystems) of biodiversity (Southerland 1998). Therefore, this chapter draws upon the data collected in the 1995 - 1997 Maryland Biological Stream Survey (MBSS or the Survey) to address the following additional components of biodiversity: species richness and distribution, rare species, vulnerable fish populations, non-native fish species, fish hybrids, and high integrity streams. A discussion of approaches to identifying centers, or "hotspots," of freshwater biodiversity using MBSS data is presented in Southerland et al. (1998, 1999).

By general scientific consensus, biodiversity is defined as (Noss and Cooperrider 1994)

> *...the variety of life and its processes. It includes the variety of organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting.*

Biodiversity can be conserved at four scales (levels of organization): genetic, species, ecosystem, and landscape (OTA 1987, CEQ 1993). The primary conservation goals at the larger scales are (1) representing all native ecosystems in a network of protected areas and (2) maintaining complete, unfragmented environmental gradients (Noss and Cooperrider 1994).

Allan and Flecker (1993) stated that "from the standpoint of biological diversity, rivers and streams are both rich in species and severely imperiled." Indeed, aquatic species are among the most endangered in the United States with a reported 28% of amphibian species, 34% of fish, and 73% of unionid mussels ranked as extinct to rare (Master 1990, Williams et al. 1989). The primary threats to conserving biodiversity in running water systems are habitat degradation and invasions of non-native species (Allan and Flecker 1993). Aquatic resources make up an important part of Maryland's biological diversity and the Ecosystem Council of Maryland DNR (1996) recognizes that conserving biodiversity is critical to its mission of managing natural resources.

To date, the ability to address aquatic biodiversity nationally or regionally has been limited by an inadequate knowledge base (Allan and Flecker 1993). Information in the MBSS can help environmental decision-makers address the conservation of biodiversity. The species occurrences in this report are statewide and represent the most comprehensive geographic data collected in a single survey. They do not, however, reflect the species occurrences or community distributions available from the Maryland Natural Heritage Program or other information sources. At present, the Survey does not address genetic diversity, nor does it define the ecosystem or landscape types found in Maryland. On the other hand, it contains detailed information on the distribution and abundance of aquatic species (especially fish) and the communities in which they reside (as measured by species composition at stream sites). The occurrence of high species numbers and rare species can be described by sample site, watershed, or river basin. Ultimately, this information may help Maryland DNR meet its goal of protecting and restoring natural ecosystems with enough native components to sustain themselves over time.

12.1 SPECIES RICHNESS AND DISTRIBUTION

The most easily understood component of biodiversity is species diversity, i.e., the number of species and how they are distributed geographically. The total number of species (species richness) is a useful way of characterizing the natural diversity of taxonomic groups in a given area. Geographically restricted species are often at greatest risk and warrant priority conservation action. The Survey provides an especially good description of the number of fish species in each sampled stream and all river basins; species and taxa numbers are less accurate (because appropriate habitats were less thoroughly searched) for benthic macroinvertebrates, amphibians and reptiles (herpetofauna), mussels, and aquatic vegetation. Nonetheless, comparisons among these different assemblages provide useful insights. The results below focus on the species or taxa richness of each river basin for these five assemblages. In addition, the richness and distribution of each assemblage across three major

geographic regions (Highlands, Eastern Piedmont, and Coastal Plain) are shown. Except where noted (i.e., core MBSS sampling only), species distributions include supplemental MBSS sampling that adds two fish species (banded darter and Atlantic menhaden) and extends the range of others (see Table 4-1 in Chapter 4).

Finer-scale presentations of native fish species richness in smaller watersheds (limited by small sample number in some watersheds) and stream sites are shown in selected figures. Analysis of these results (using only fish species captured in the core MBSS sampling) indicates that a relatively small subset of the Maryland 8-digit watersheds (11 or 8% of the 138 watersheds in Maryland) captures all the fish species sampled by the Survey and that a single watershed, the Anacostia, captures 45% of the species (Southerland et al. 1999). Similar figures of taxa richness patterns for benthic macroinvertebrates and amphibians and reptiles are included in Southerland et al. (1998).

12.1.1 Fish

The total complement of fish species sampled by the Survey is not exhaustive (it misses about half of the rarest species listed by the Maryland Natural Heritage Program), but it provides the most accurate species richness numbers to date for all parts of the State. Figure 12-1 illustrates the number of native fish species present at each core MBSS sample stream site. The most species-rich sites are in the central part of the State, but are scattered over more than one-third of Maryland. It should be noted that these species numbers are a combination of natural species richness and impacts of anthropogenic activities.

Among the 17 river basins in Maryland, the number of all fish species (native and non-native) sampled ranged from 28 in the Youghiogheny basin to 57 in the Patuxent basin (Figure 12-2). Only three fish species (largemouth bass, bluegill, and pumpkinseed) were present in all 17 river basins. None of these statewide ranges are natural; largemouth bass and bluegill were introduced to the Chesapeake Bay drainage and pumpkinseed was introduced to the Youghiogheny basin. On the other end of the spectrum, six basins (Youghiogheny, Lower Potomac, Patuxent, Susquehanna, Chester, and Pocomoke) contained one or two fish species (including johnny darter, striped shiner, flier, shorthead redhorse, stripeback darter, banded darter, Atlantic menhaden, and longnose gar) unique to that basin. Therefore, most of the 85 fish species collected were found in more than one, but not all, river basins in Maryland.

When the distribution of fish species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 51 occurred in all three regions and less than 10 are unique to any one region (Figure 12-2). In no case did a fish species occur in the Highlands and Coastal Plain, but not in the Piedmont. Table 4-1 and the discussion in Chapter 4 describe the distributions of individual fish species in more detail.

12.1.2 Benthic Macroinvertebrates

Information on the taxonomic diversity of benthic macroinvertebrates was enhanced for this statewide report by identifying this component of the aquatic community to the genus, or lowest practicable taxon, level. Although previous analyses at the family level were useful, genera were used in this report because they more closely describe the ecological roles and contribution to biodiversity of benthic macroinvertebrates. It should be noted that the presence of taxa at each sample site only reflects those captured in the 100-organism subsamples. While subsamples effectively characterize the benthic macroinvertebrate communities in these streams, rare taxa were undoubtedly missed at many sites.

Among the 17 river basins in Maryland, the number of all benthic macroinvertebrate taxa sampled ranged from 83 in the Elk and Bush basins to 190 in the Lower Potomac basin (Figure 12-3). Only 14 benthic macroinvertebrate taxa were present in all 17 river basins. On the other end of the spectrum, the Bush basin did not contain any benthic macroinvertebrate taxa unique to that basin. In no basin did the percentage of taxa unique to the basin exceed 10%. Therefore, most of the 346 benthic macroinvertebrate taxa collected were found in more than one, but not all, river basins in Maryland.

When the distribution of benthic macroinvertebrate taxa among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, the majority (122) occurred in all three regions and less than 30 are unique to any one region (Figure 12-3).

12.1.3 Amphibians and Reptiles

The amphibian and reptile species collected by the Survey are a sample of those species that reside in streams and their riparian zones. These amphibian and reptiles are a subset of the larger herpetofauna of the State that include many primarily terrestrial species. The 45 species collected

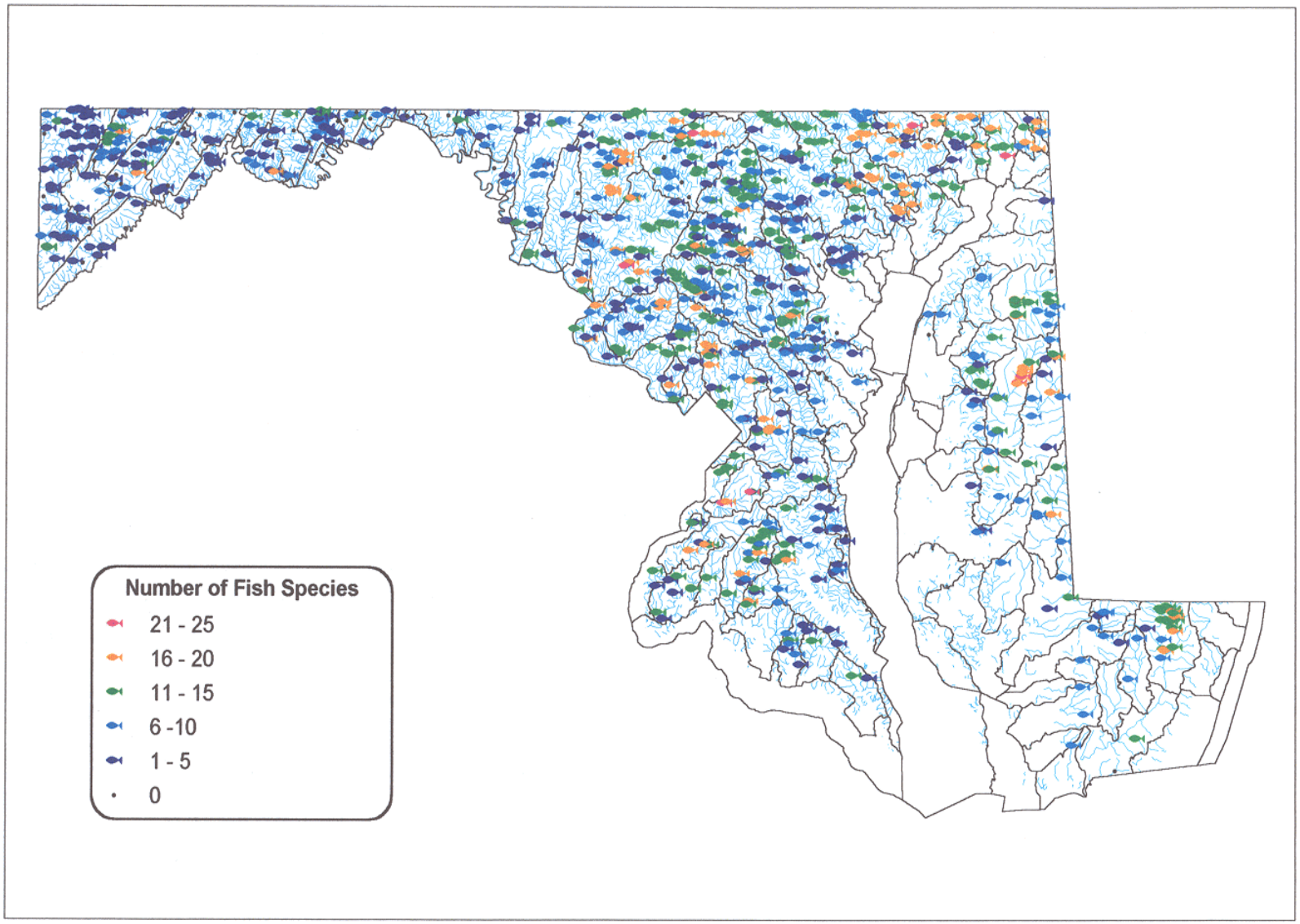

Figure 12-1. Native fish species richness by site for the 1995 - 1997 MBSS

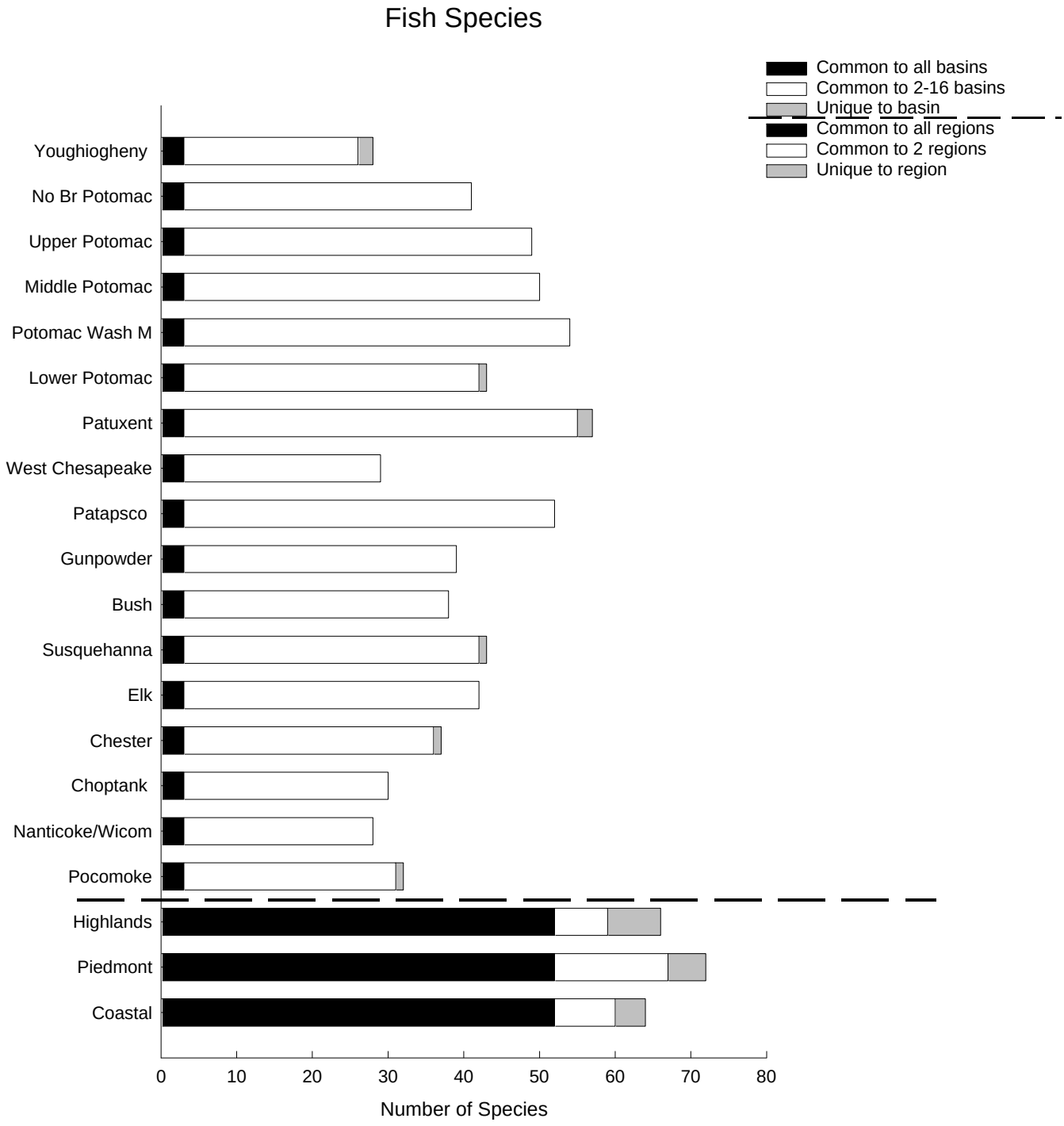

Figure 12-2. Fish species richness by basin and geographic region for the 1995-1997 MBSS

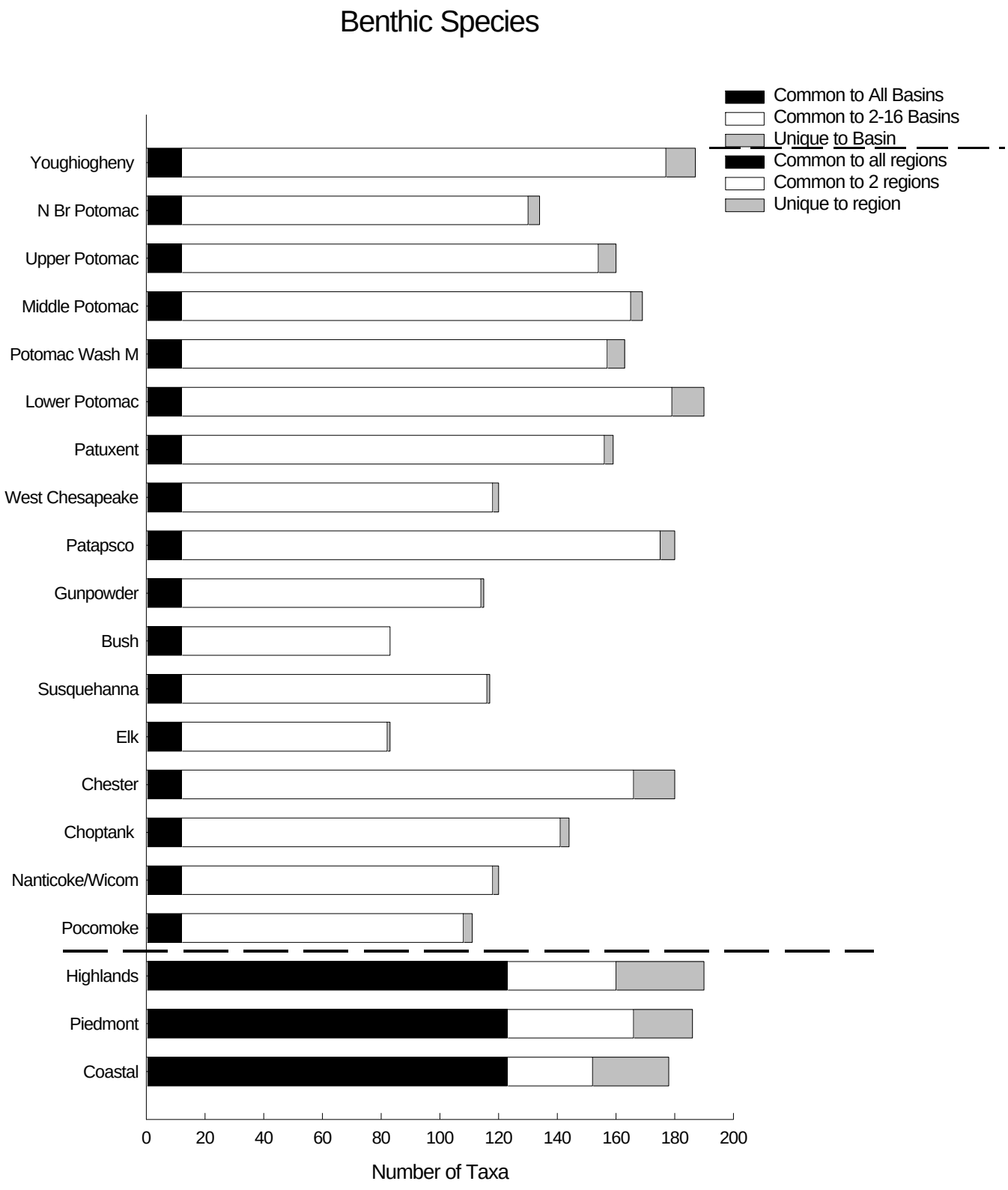

Figure 12-3. Benthic species richness by basin and geographic region for the 1995-1997 MBSS

their riparian zones. These amphibian and reptiles are a subset of the larger herpetofauna of the State that include many primarily terrestrial species. The 45 species collected by the Survey represent 56% of the amphibians and 40% of the reptiles reported by Maryland DNR to exist in the State. Because the Survey focuses on streams and riparian areas, we have looked both at the species richness and distribution of all amphibian and reptile species and those that are dependent on aquatic systems (Figure 12-4). Interestingly, although the number of aquatic-dependent species found is on average 60% less than the total, the pattern of species richness across the three major geographic regions (Highlands, Eastern Piedmont, and Coastal Plain) and the 17 basins is virtually the same. Therefore, the following discussion includes all the amphibian and reptile species sampled by the Survey in 1995 to1997.

In general, the statewide pattern of total amphibian and reptile species richness declines from the western to eastern parts of the State (Figure 12-5). Among the 17 basins in Maryland, the number of all amphibian and reptile species sampled ranged from 9 in the Nanticoke/Wicomico to 26 in the Patuxent. Only two amphibian (green frog and bullfrog) and one reptile (northern water snake) species were present in all 17 basins. At the other extreme, six basins (Youghiogheny, North Branch Potomac, Upper Potomac, Patuxent, Choptank, and Nanticoke/Wicomico) contained one or two amphibian or reptile species (including Jefferson salamander, northern fence lizard, gray treefrog, redbelly turtle, eastern smooth earth snake, rough green snake, and smooth green snake) unique to that basin. Therefore, most of the 45 amphibian and reptile species collected were found in more than one, but not all, river basins in Maryland.

When the distribution of amphibian and reptile species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 18 occur in all three regions with the number of species unique to one region ranging from 2 in the Coastal Plain to 6 in the Highlands (Figure 12-5). As would be expected (given their different ecological requirements), the species richness patterns for each herpetofaunal organism group vary and are discussed separately below.

Salamander species richness showed the most striking geographic variation; it was highest in the western basins, with 9 to 11 observed species in the Youghiogheny, North Branch Potomac, and Upper Potomac basins (Figure 12-6). The only species unique to a single basin (North Branch Potomac) was the Jefferson salamander (*Ambystoma jeffersonianum*). This species was the only amphibian or reptile found by the Survey that is on the Maryland DNR (1997) listing of state-listed endangered, threatened, or species of special concern.

Frog and toad species richness was fairly evenly distributed across the 17 basins, ranging from four species in three basins to a high of 10 species in the Patuxent basin (Figure 12-7). While most of the 11 species were widespread, the gray treefrog and northern cricket frog were found in only one or two basins (Lower Potomac and Patuxent).

The number of turtle species increased in the more southern basins, ranging from one to five species per basin (Figure 12-8). A terrestrial species, the eastern box turtle, was found in 14 of the basins, while redbelly and spotted turtles were found in only one or two basins (Middle Potomac, Potomac Washington Metro, and Nanticoke/Wicomico).

The number of snake and lizard species declined slightly in eastern basins, ranging from one species in Nanticoke/Wicomico to seven in Upper Potomac (Figure 12-9). The aquatic northern water snake was observed in all 17 basins, while six species were found in only one or two basins.

12.1.4 Mussels

Freshwater mussels in the eastern United States are one of the most imperiled faunas in the nation (Master 1990, Williams et al. 1989). In Maryland, there are 18 species of freshwater unionid bivalves. Two species, eastern elliptio (*Elliptio complanata*) and the eastern floater (*Pyganodon cataracta*) occur most commonly and are the most abundant species. The plain pocketbook (*Lampsilis cardium*) has been introduced into the Potomac River, presumably as a result of fish stocking. Additionally, the Asiatic clam (*Corbicula fluminea*) has been introduced throughout Maryland.

Fourteen species of freshwater unionid mussels are listed as rare or endangered in Maryland (MDNR 1997). The dwarf wedge mussel (*Alasmidonta heterodon*) is listed both as state and federally endangered, while three other species, the triangle floater (*Alasmidonta undulata*), brook floater (*Alasmidonta varicosa*), and green floater *(Lasmigona subviridis*) are listed as state endangered and are candidates for federal listing. Yellow lampmussel (*Lampsilis cariosa*) is considered extirpated in Maryland. Nine other species are listed as rare (Table 12-1). There is also concern about the status of several other species such as the elktoe (*Alasmidonta marginata*), which has not been found in recent years (Karene Motivans, MDNR, personal communication).

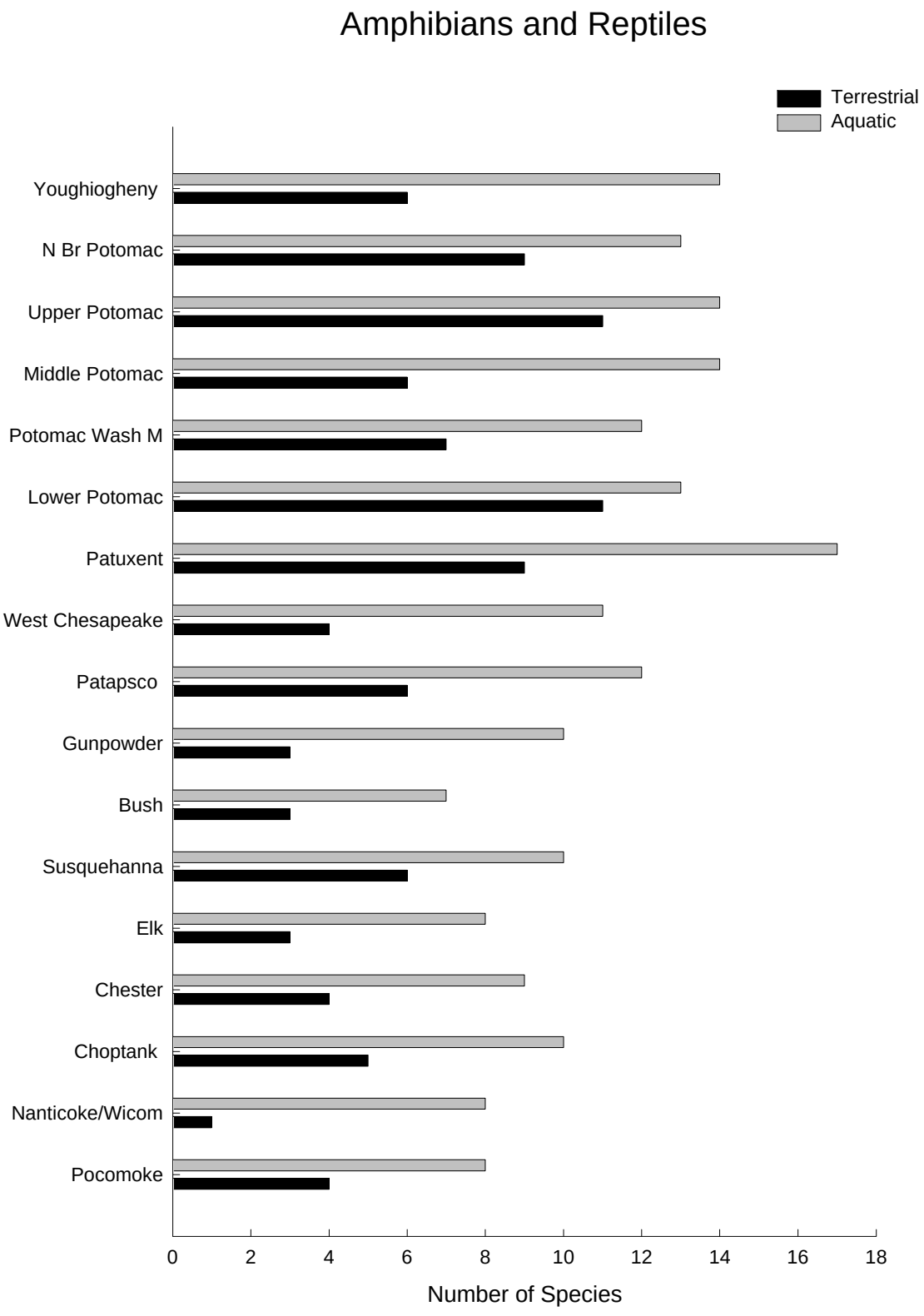

Figure 12-4. Terrestrial and aquatic amphibian and reptile species richness by basin for the 1995-1997 MBSS

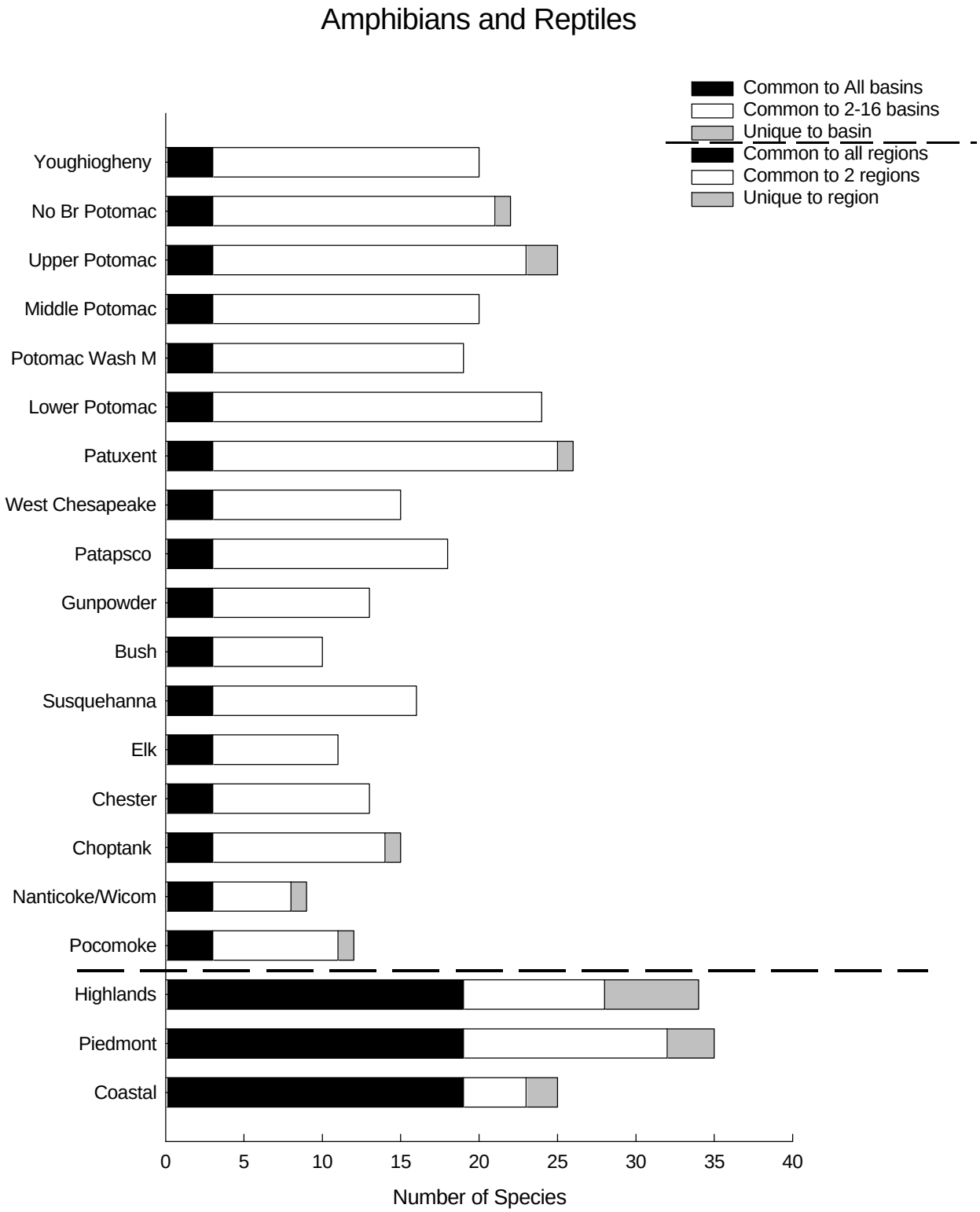

Figure 12-5. Total amphibian and reptile species richness by basin and geographic region for the 1995-1997 MBSS

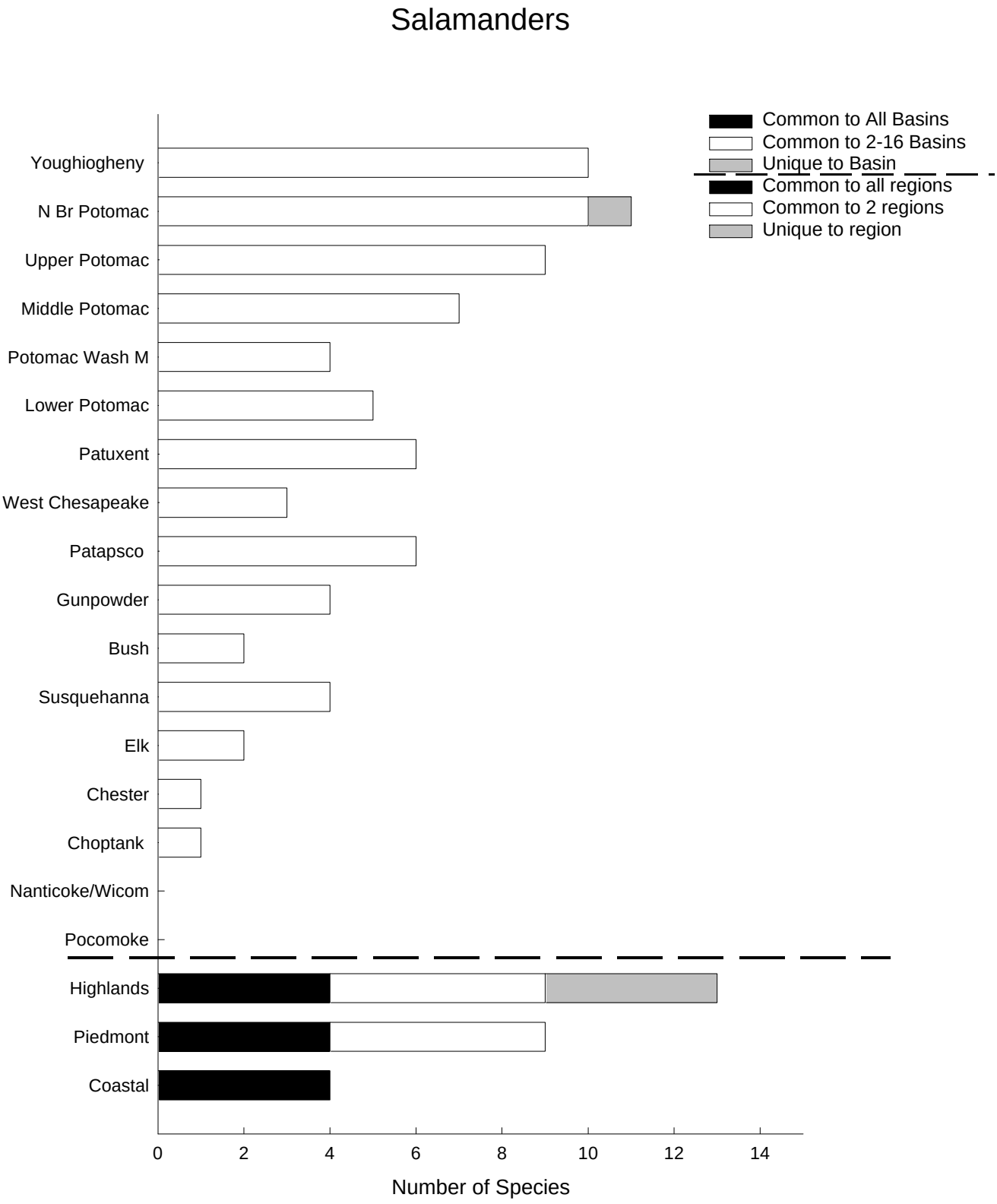

Figure 12-6. Salamander species richness by basin and geographic region for the 1995-1997 MBSS

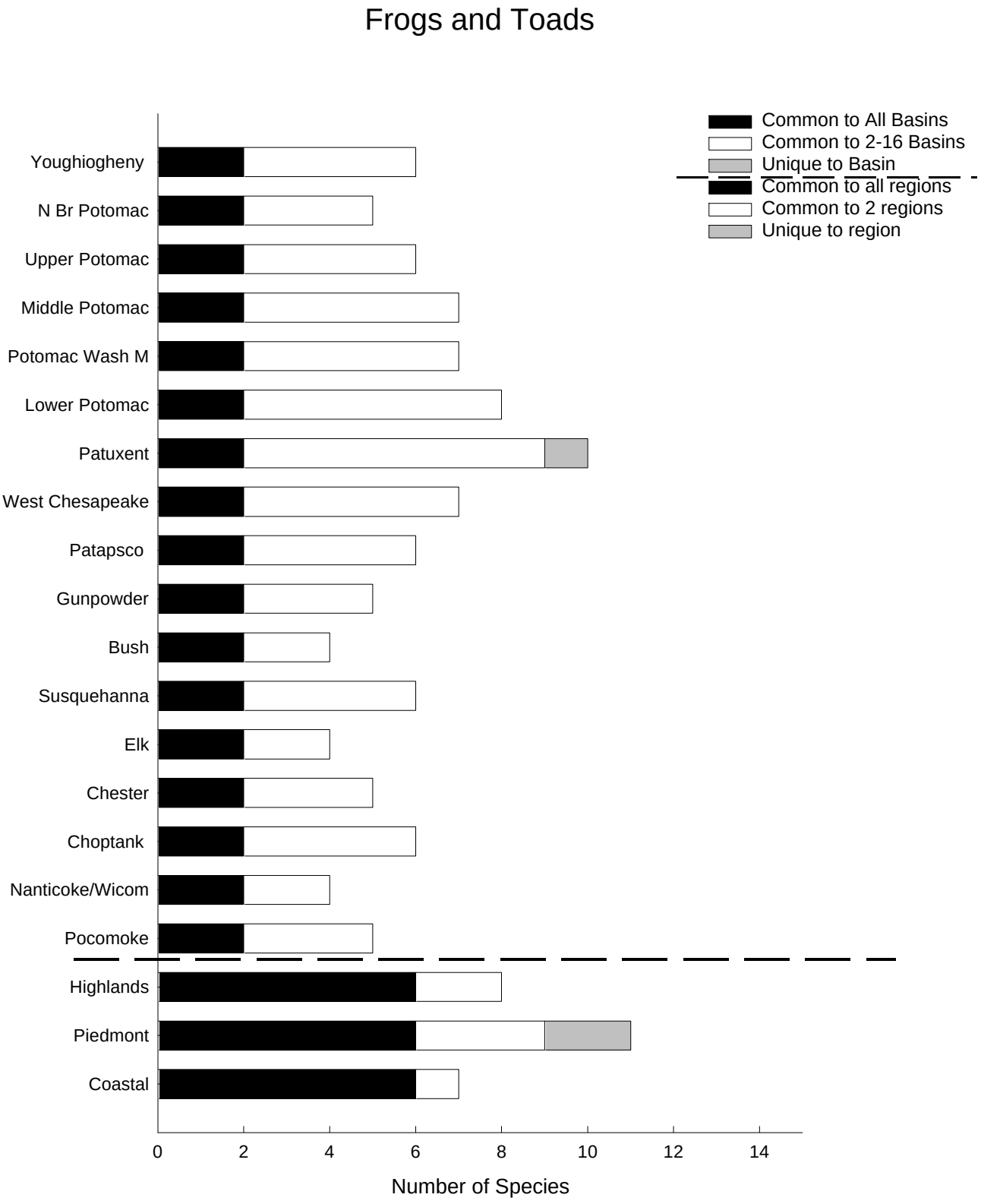

Figure 12-7. Frog and toad species richness by basin and geographic region for the 1995-1997 MBSS

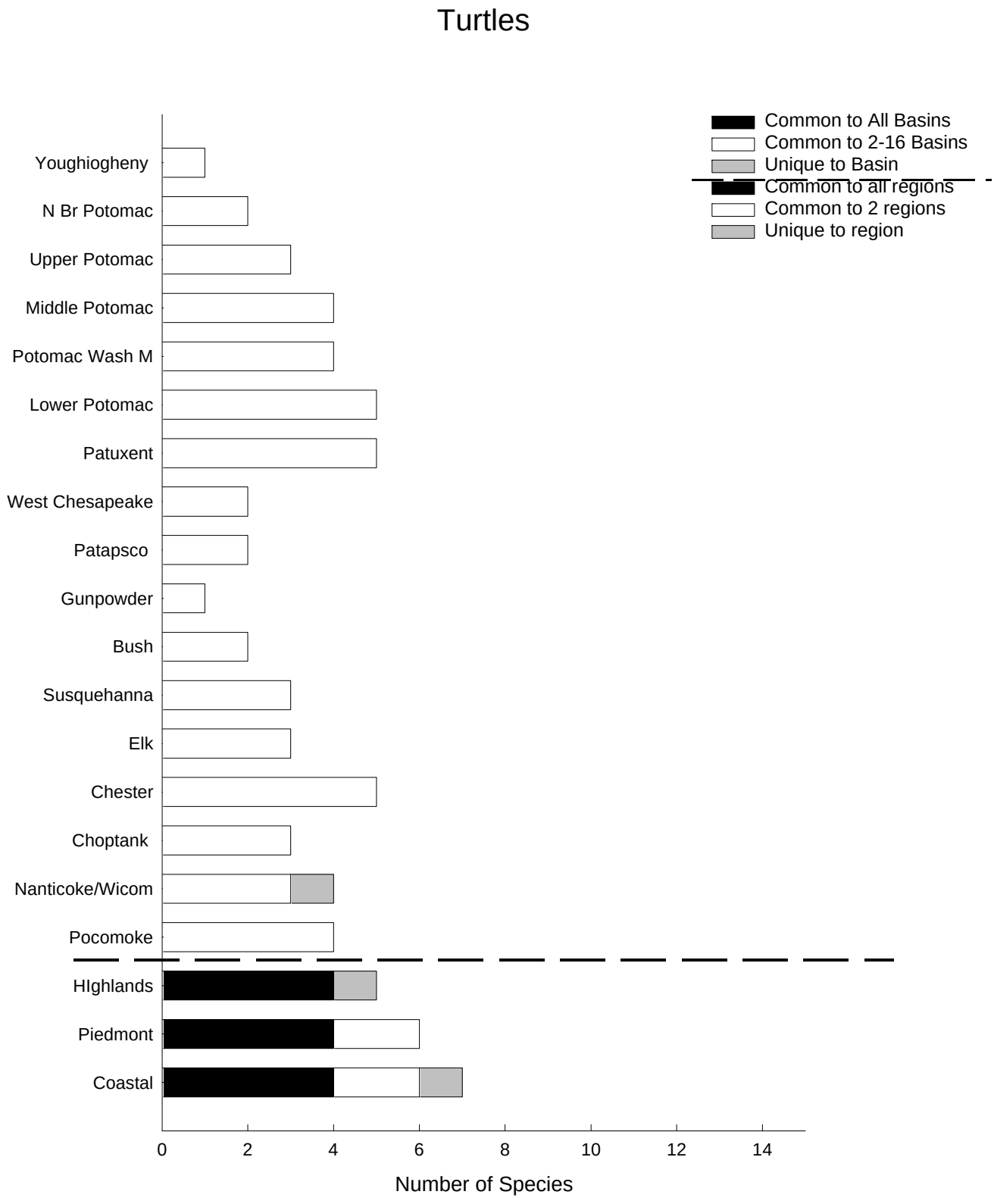

Figure 12-8. Turtle species richness by basin and geographic region for the 1995-1997 MBSS

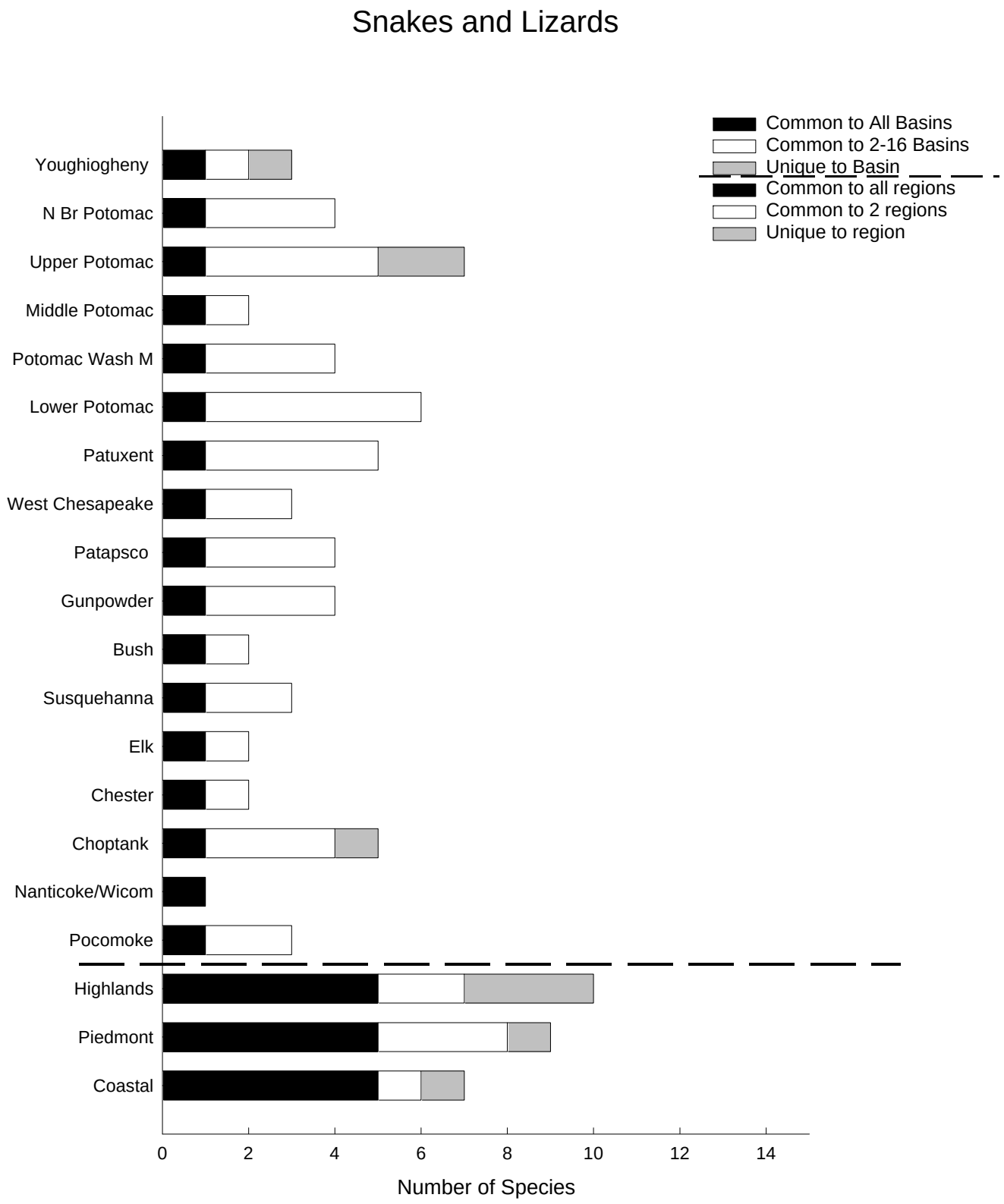

Figure 12-9. Snake and lizard species richness by basin and geographic region for the 1995-1997 MBSS

Table 12-1. Freshwater unionid mussel species listed as rare, threatened, or endangered in Maryland (MDNR 1997)

Common Name	Scientific Name	Status
Dwarf wedge mussel	*Alasmidonta heterodon*	State and Federal Endangered
Triangle floater	*Alasmidonta undulata*	State Endangered
Brook floater	*Alasmidonta varicosa*	State Endangered
Alewife floater	*Anodonta implicata*	Rare
Northern lance	*Elliptio fisheriana*	Rare
Yellow lance	*Elliptio lanceolata*	Rare
Atlantic spike	*Elliptio producta*	Rare
Yellow lampmussel	*Lampsilis cariosa*	State Endangered Extirpated
Eastern lampmussel	*Lampsilis radiata*	Rare
Green floater	*Lasmigona subviridis*	State Endangered
Tidewater mucket	*Leptodea ochracea*	Rare
Eastern pondmussel	*Ligumia nasuta*	Rare
Squawfoot	*Strophitus undulatus*	Rare
Paper pondshell	*Utterbackia imbecillis*	Rare

There is still considerable controversy over the nomenclature of various relatively small, elongated, freshwater mussels collectively referred to as the lanceolate *Elliptio* complex (Johnson 1970). This complex comprises what may or may not be several distinct species. Generally, only electrophoresis (a process by which proteins can be separated) or DNA testing can be used to accurately separate one species from another. Based upon electrophoretic studies, Davis et al. (1981) suggest that the number of species of lanceolate elliptios has been greatly underestimated. As a result, there is ongoing controversy about whether the species of lanceolate *Elliptio* that are found in Maryland are actually the Atlantic spike (*E. producta*), northern lance (*E. fisheriana*), Carolina lance (*E. angustata*), yellow lance (*E. lanceolata*), or still another species. In Maryland, it has been commonly assumed that the most common lanceolate *Elliptio* species are the northern lance on the eastern shore, and the Atlantic spike on the western shore.

Statewide, seven species of freshwater unionid mussels were observed during MBSS sampling in 1995 to 1997, including four species listed as rare or endangered in Maryland: alewife floater, northern lance, squawfoot, and yellow lance. Overall, freshwater unionid mussels were found at 9.9% (90) of the sites sampled. Unionid mussels were collected in only 1.7% of the first-order sites, 9.5% of the second-order sites, and 19% of the third-order sites.

Only five basins contained more than two mussel species and the North Branch Potomac contained none (Figure 12-10). The Chester contained the most species with six, including one (yellow lance) found only in that basin. The only other mussel species unique to a single basin was the squawfoot in the Middle Potomac.

When the distribution of native mussel species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, three occurred in all three regions, while one was unique to the Highlands and two were unique to the Coastal Plain (Figure 12-10).

12.1.5 Aquatic Vegetation

During the MBSS sampling in 1995 to 1997, 12 species of submerged aquatic vegetation (SAV), 10 species of emergent vegetation, and 2 species of floating vegetation were observed. The number of species of aquatic vegetation ranged from zero in the North Branch Potomac to 12 in the Choptank (Figure 12-11). Only the Choptank basin contained more than 10 aquatic plant species; three basins contained seven to 10 species. Five basins (Middle Potomac, Potomac Washington Metro, Lower Potomac, Bush, and Choptank) each contained one species unique to that basin.

When the distribution of aquatic vegetation species among three major geographic regions—Highlands, Eastern Piedmont, and Coastal Plain—is considered, 9 occurred in all three regions, while 2 to 4 were unique to any one region (Figure 12-11).

12.2 RARE SPECIES

The Survey can provide information on the occurrence and abundance of State rare, threatened, or endangered species.

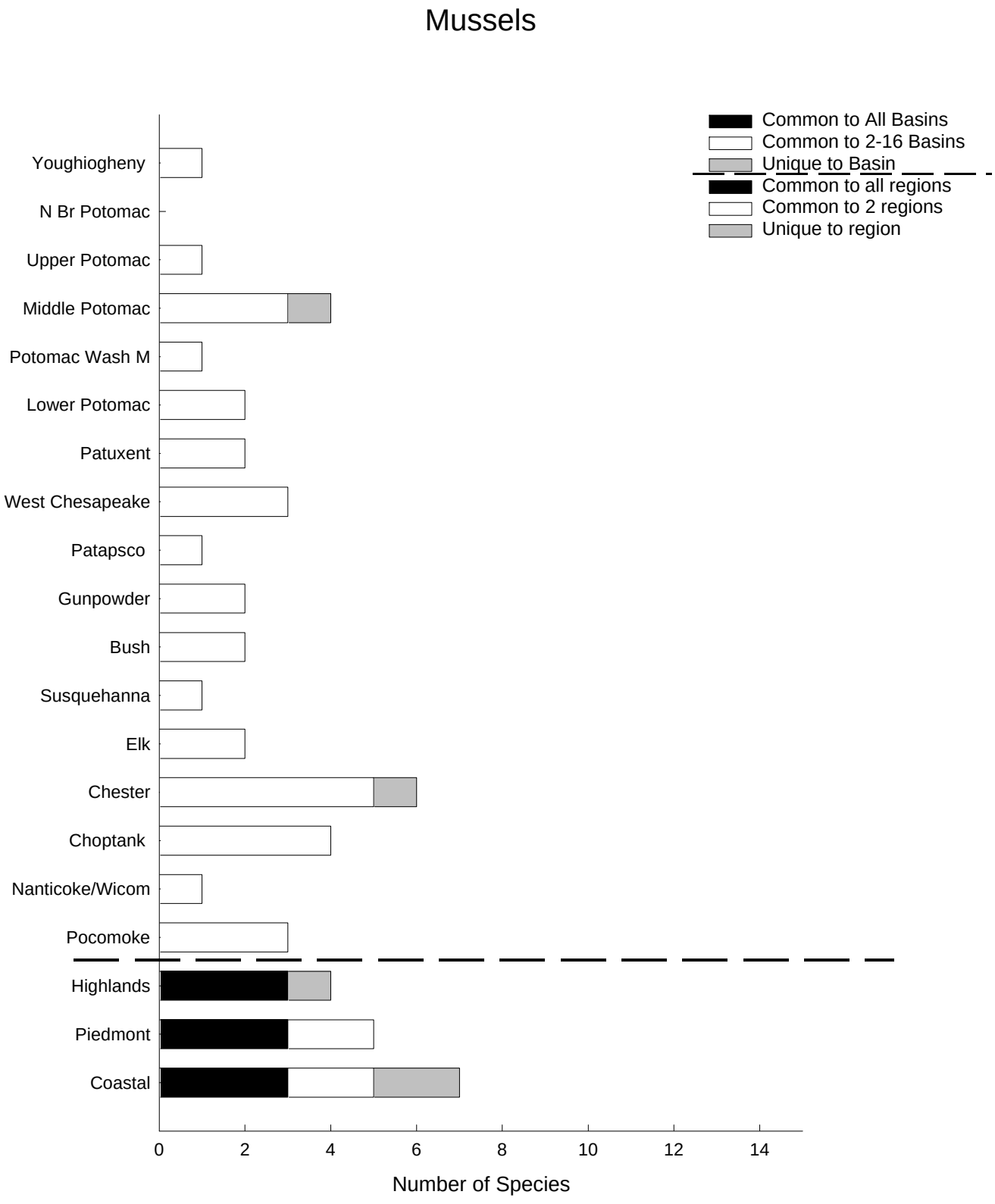

Figure 12-10. Mussel species richness by basin and geographic region for the 1995-1997 MBSS

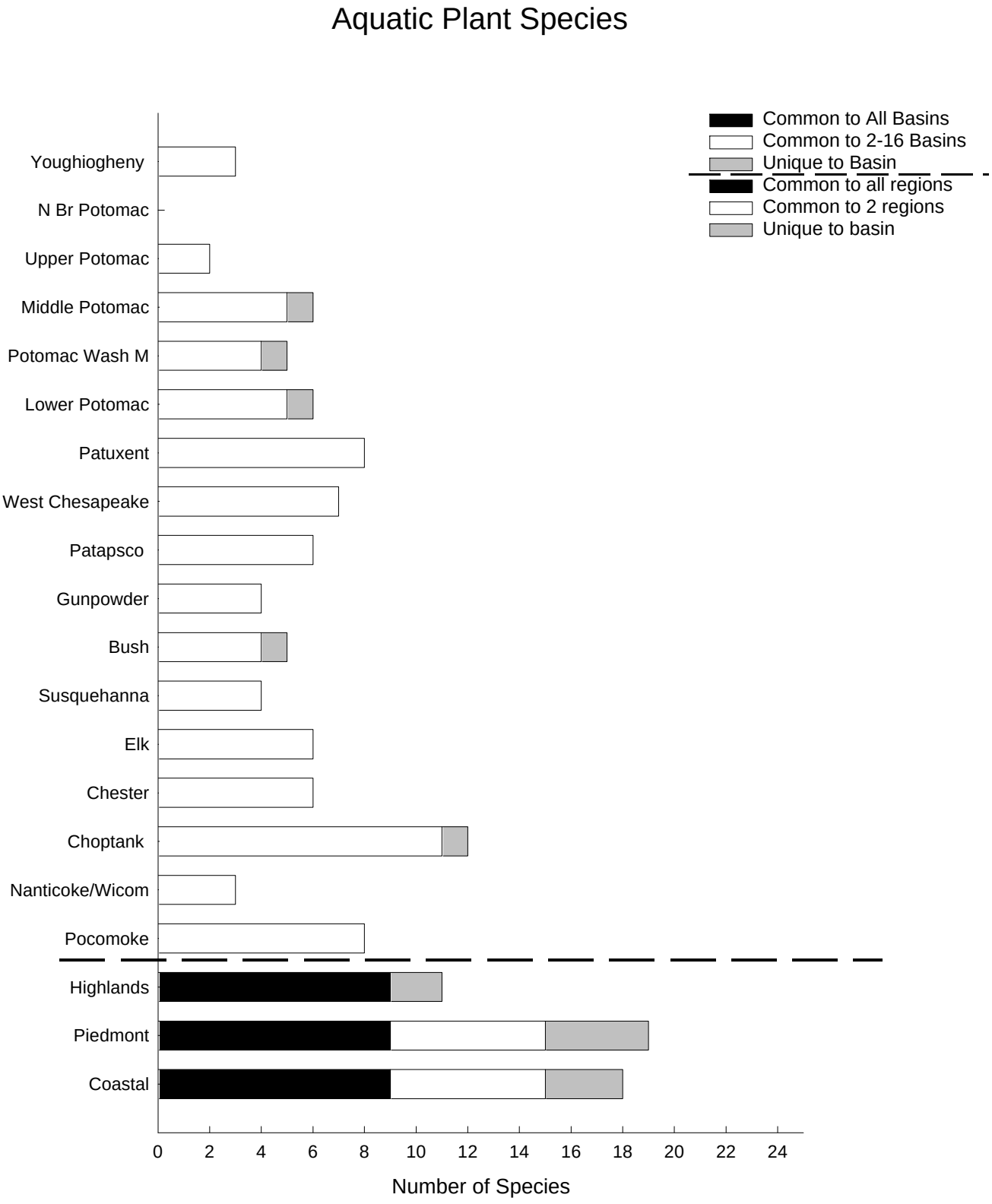

Figure 12-11. Aquatic plant species richness by basin and geographic region for the 1995-1997 MBSS

A state list of rare species is maintained by Maryland DNR's Heritage and Wildlife Division based on evidence from numerous sources, including historical data and more recent field investigations (MDNR 1997). Each species is assigned a state rank; some species also have a state status as endangered or threatened that carries legal protection. Six fish, one amphibian, and five mussel species listed by the Maryland DNR (1997) Natural Heritage Program were captured by the Survey in 1995 to 1997:

- Stripeback darter (*Percina notogramma*) - Highly state rare, state endangered extirpated
- Glassy darter (*Etheostoma vitreum)* - Highly state rare, state endangered
- Ironcolor shiner (*Notropis chalybaeus*) - Highly state rare
- Logperch (*Percina caprodes*) - Highly state rare
- Mud sunfish (*Acantharchus pomotis*) - State rare
- Flier (*Centrarchus macropterus*) - State status uncertain, but possibly rare

- Jefferson salamander (*Ambystoma jeffersonianum*) - State watch list
- Alewife floater (*Anodonta implicata*) - State rare
- Atlantic spike (*Elliptio producta*) - State rare
- Northern lance (*Elliptio fisheriana*) - State rare
- Squawfoot (*Strophitus undulatus*) - State rare
- Yellow lance (*Elliptio lanceolata*) - State rare

No federally-listed threatened or endangered species were found by the survey.

Although state-listed rare and endangered fish are found in several sub-basins throughout Maryland, some areas, like Zekiah Swamp in the Lower Potomac basin, Tuckahoe Creek in the Choptank basin, and the Upper Pocomoke River, have up to four such species in their watersheds (Figure 12-12). Watersheds of the Casselman River in the Youghiogheny basin, Lower Monocacy River in the Middle Potomac basin, Western Branch of the Patuxent River, and the Pocomoke River each contain up to three rare, threatened or endangered fish species.

Because the core Survey uses a probability-based sampling design, we were able to develop an independent list of rare fish species. For the purposes of this analysis, we defined

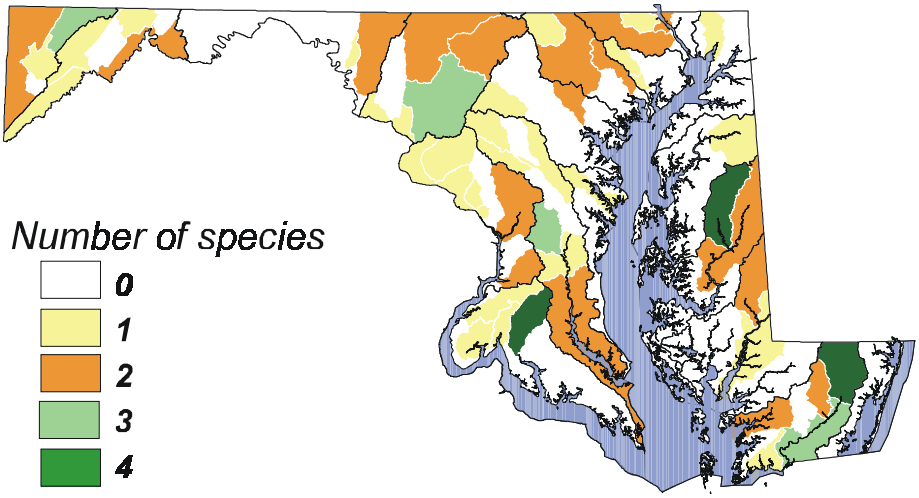

Figure 12-12. Distribution of state-listed rare and endangered fish found in the 1995 - 1997 MBSS, by watershed

as rare those fish species occurring at approximately 2% or fewer of the 905 randomly selected MBSS sites sampled in 1995 to 1997 (species known to be more abundant in large streams or tidal waters not sampled by the Survey were excluded from the list). Table 12-2 presents the first statistically reliable estimates of fish species rarity (percentage of stream sites where present) in Maryland. Designation as rare was corroborated by the population abundance estimates for these species, 11 of which were below 25,000 individuals statewide.

All of the Heritage-listed species captured by the Survey met our 2% sampling-based definition of rarity, confirming the status of these species as geographically rare. Those species found at less than 2% of MBSS sites are overlain on a map of watershed fish species richness in Figure 12-13. Clusters of sites with one to four rare fish species occur in five areas of the State.

12.3 VULNERABLE FISH POPULATIONS

Although the size of fish populations that can effectively sustain themselves over time may vary widely and is not generally known, low population size usually indicates increased risk of extirpation in a basin (for this analysis, 500 individuals was chosen as a threshold representing the low end of estimates calculated for all fish species collected). The Survey has the ability to provide precise estimates of non-tidal stream fish populations in each sampled basin. Using 1995-1997 MBSS data, a fish population was characterized as being at greater risk of extirpation if (1) the estimated population size in a basin was 500 individuals or less and (2) the distribution of the species was expected or known to be primarily restricted to first through third order non-tidal streams. For example, *Fundulus* sp. (killifish) non-tidal populations of less than 500 were not considered at risk because the group occurs extensively in tidal streams

Table 12-2. Rare fish species occurring at approximately 2% or fewer MBSS sites

Species	Percentage of Sites	Total Abundance[+]
Rainbow darter	**0.11**	**124**
Logperch*	**0.22**	**8,185**
Stripeback darter*	**1**	**580**
Flier*	**0.44**	**1335**
Glassy darter*	**0.55**	**4825**
Ironcolor shiner*	**0.66**	**2919**
Comely shiner	**0.77**	**3,639**
Striped shiner	**0.77**	**10,152**
American brook lamprey	**1.2**	**178,009**
Checkered sculpin	**1.2**	**475,984**
Mud sunfish*	**1.3**	**3,519**
Warmouth	**1.3**	**24,005**
Pearl dace	**1.4**	**497,025**
Johnny darter	**1.6**	**77,012**
Swamp darter	**2.2**	**9,286**

***On Maryland State Heritage List**
[+]Statewide estimate adjusted for capture efficiency

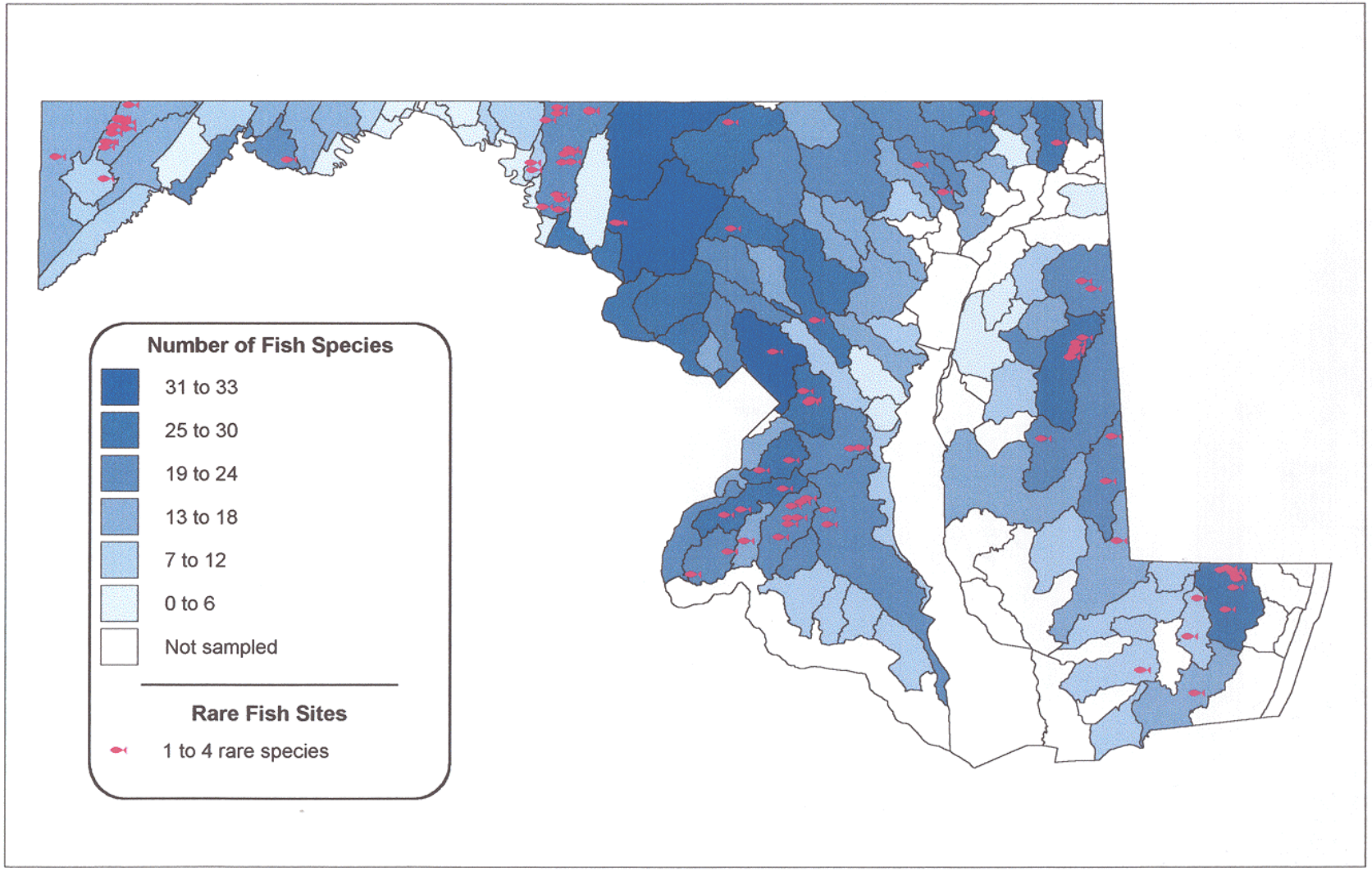

Figure 12-13. Overlay of watershed fish species richness and sites with rare fish species

Figure 12-13. Overlay of watershed fish species richness and sites with rare fish species

and embayments. Non-native fish were also not considered in this analysis.

Of the 17 basins in Maryland, only the Nanticoke/Wicomico did not contain a fish population with less than 500 individuals (based on adjusted population estimates). One to four species with populations less than 500 were found in the other 16 basins (Table 12-3). Of those populations potentially at greater risk of extirpation, ten populations met the MBSS criteria of being rare based on occurrence at less than 2% of sample sites (see section 12.2): striped shiner (Youghiogheny 1997), rainbow darter (North Branch Potomac), American brook lamprey (Potomac Washington Metro), swamp darter (Lower Potomac, Chester, Choptank 1996), logperch (Elk), ironcolor shiner (Choptank 1996), mud sunfish (Choptank 1996), and glassy darter (Pocomoke). The remaining 30 populations with less than 500 individuals represent more widespread species that are either at the edge of their range or are suffering declines from anthropogenic influences.

For example, populations of redfin pickerel (*Esox americanus*) and creek chubsucker (*Erimyzon oblongus*), two species common to Maryland's Coastal Plain, may be at risk in the Patapsco basin because there is little Coastal Plain habitat. In addition, what little Coastal Plain and wetland habitat occurs in this basin appears to be suffering losses from anthropogenic activities. Similarly, the eastern mudminnow, an extremely abundant Coastal Plain species, is vulnerable in the Bush basin, where it is on the edge of its natural range. In another example, the sea lamprey, a species abundant in much of North America, appears to be uncommon throughout Maryland. This is likely the result of numerous migration barriers and the susceptibility of larval lampreys to periodic water quality problems.

12.4 FISH HYBRIDS

Hybridization sometimes occurs when species are brought together through range expansions or habitat homogenization (usually as a result of environmental degradation). Hybridization can also result from introductions of non-native species such as some members of the genus *Lepomis*. A total of 63 hybrids (47 *Lepomis*, 16 cyprinids) were collected by the Survey in 1995 to 1997. Nearly 80% of the *Lepomis* hybrids were observed in the Upper Potomac (23) and Middle Potomac (14) basins. All but one of the cyprinid hybrids were observed in the Bush basin. Hybrids represented the highest percentage in the Middle Potomac basin at 1%; the percentage of hybrids was at least an order of magnitude less in all other basins.

12.5 NON-NATIVE SPECIES

There has been considerable debate over the virtues and threats of introduced species, especially those "naturalized" species (e.g., valued game fish species) that have been part of Maryland stream communities for decades. The conservation of biodiversity does not address recreational fisheries benefits, but rather focuses on maintaining native species as representatives of co-evolved natural systems. Although introduced gamefish species may benefit recreational fishermen, they may adversely affect the native fish community and thus degrade biodiversity. The invasion of non-native molluscs also has the potential to degrade the imperiled native mussel fauna and otherwise adversely affect natural ecosystems. The Chesapeake Bay Program recognizes this potential for deleterious effects in its policy guidelines on the introduction of non-native aquatic species into the Chesapeake Bay drainage (Chesapeake Bay Program 1993).

One of the most dramatic examples of expansion by a non-native aquatic species in Maryland is the Asiatic clam, *Corbicula fluminea* (Phelps 1994). First introduced into the Potomac River in the mid-1970s, the Asiatic clam has expanded its range into 13 of the 17 river basins in Maryland according to the results of the 1995-1997 MBSS. Although it occurred in most basins, the Asiatic clam found in relatively few sites in each basin (Figure 12-14). Statewide, the Asiatic clams was found at 7.7% (70) of the sites sampled, ranging from 0.7% of first-order streams to 5.1% of second-order to 18% of third-order. The troublesome non-native zebra mussel, *Dreissena polymorpha*, was not found during 1995-1997 MBSS sampling, but it should be noted that the habitat requirements of the zebra mussel are very similar to those of the Asiatic clam (Claudi and Mackie 1994).

How pervasive non-native fish species are in each basin is an important indicator of loss of biodiversity. Where non-native species make up a large proportion of the number of species or individuals in a basin, the natural ecological or evolutionary processes of the fish communities have likely been substantially altered. An analysis of the relative proportion of non-native fish per stream mile in each basin reveals substantial differences among basins with generally higher occurrences farther east (Figure 12-15). The density (and relative proportion) of non-native fish was greatest in the Nanticoke/Wicomico basin (1,225 non-native fish per mile, 24% of the total number of fish per mile) and lowest in the North Branch Potomac basin (32 non-native fish per mile, 1.2% of the total).

Table 12-3. Vulnerable fish species by basin (population less than 500) for the 1995-1997 MBSS, non-tidal, small streams only

	Adjusted Abundance	Standard Error
Youghiogheny 1997		
Green sunfish	110	114
Smallmouth bass	264	243
Striped shiner	330	330
Bluegill	440	451
North Branch Potomac		
Creek chubsucker	144	133
Rainbow darter	144	144
Pumpkinseed	212	133
Upper Potomac		
River chub	61	61
Northern hogsucker	490	368
Middle Potomac		
Swallowtail shiner	272	242
Creek chubsucker	471	284
Potomac Washington Metro		
Bluespotted sunfish	65	53
Redfin pickerel	194	194
American brook lamprey	362	270
Lower Potomac		
Swamp darter	138	94
Common shiner	268	281
Patuxent		
Chain pickerel	121	141
Bluntnose minnow	134	112
West Chesapeake		
Swallowtail shiner	19	19
Redbreast sunfish	19	21
Satinfin shiner	154	123

Table 12-3. Cont'd

	Adjusted Abundance	Standard Error
Patapsco 1995		
Creek chubsucker	125	129
Bluespotted sunfish	258	258
Chain pickerel	322	275
Patapsco 1996		
Redfin pickerel	345	345
Creek chubsucker	460	507
Gunpowder		
Fallfish	123	113
Bush		
Sea lamprey	287	264
Eastern mudminnow	469	457
Susquehanna		
Golden shiner	172	100
Elk		
Least brook lamprey	61	53
Logperch	182	182
Chester		
Sea lamprey	71	40
Rosyside dace	115	102
Swamp darter	472	340
Choptank 1996		
Swamp darter	115	92
Ironcolor shiner	138	84
Mud sunfish	138	85
Pocomoke		
Glassy darter	49	33
Chain pickerel	110	86

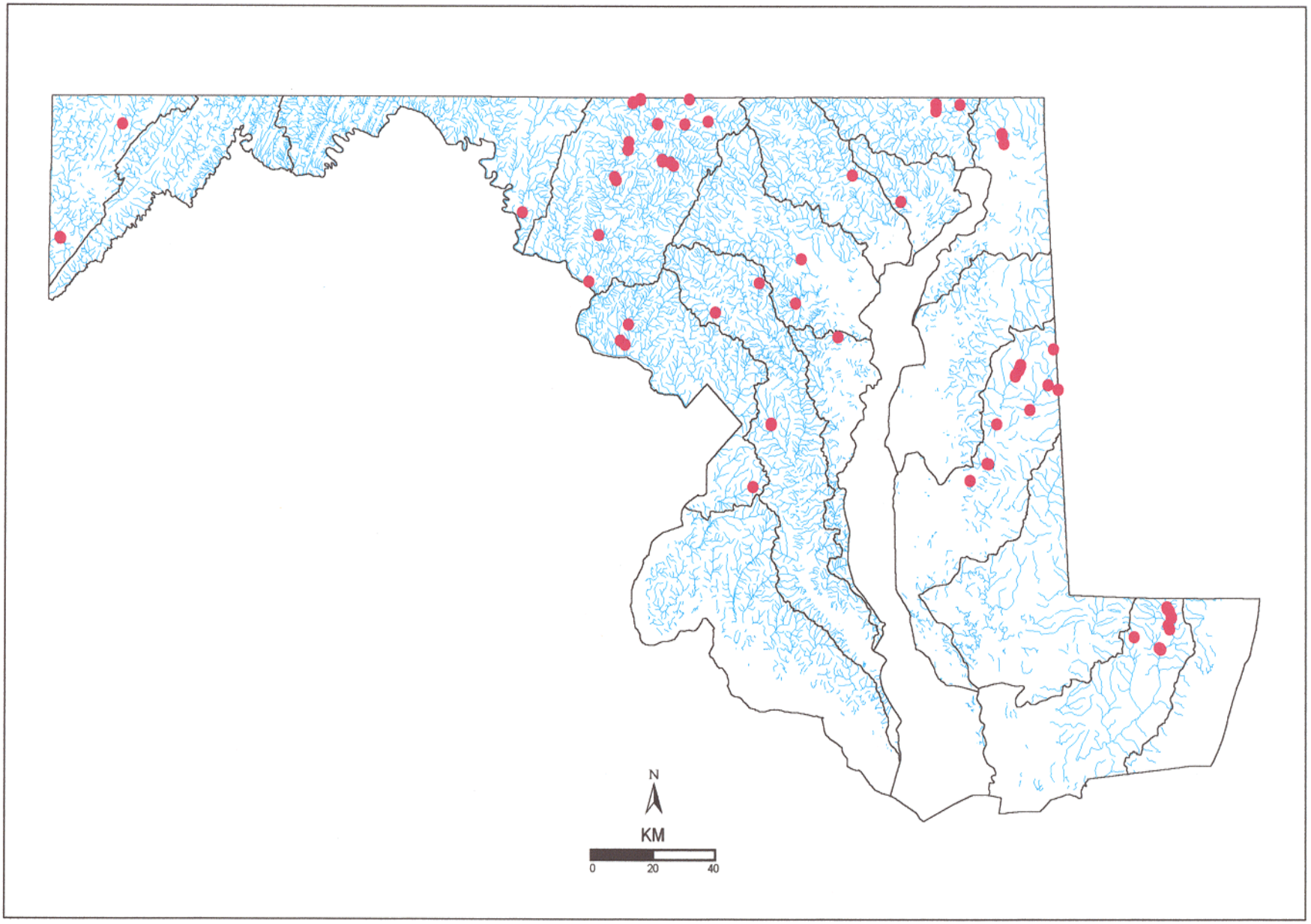

Figure 12-14. Presence of Asiatic clam (*Corbicula fluminea*) at 1995-1997 MBSS sampling sites

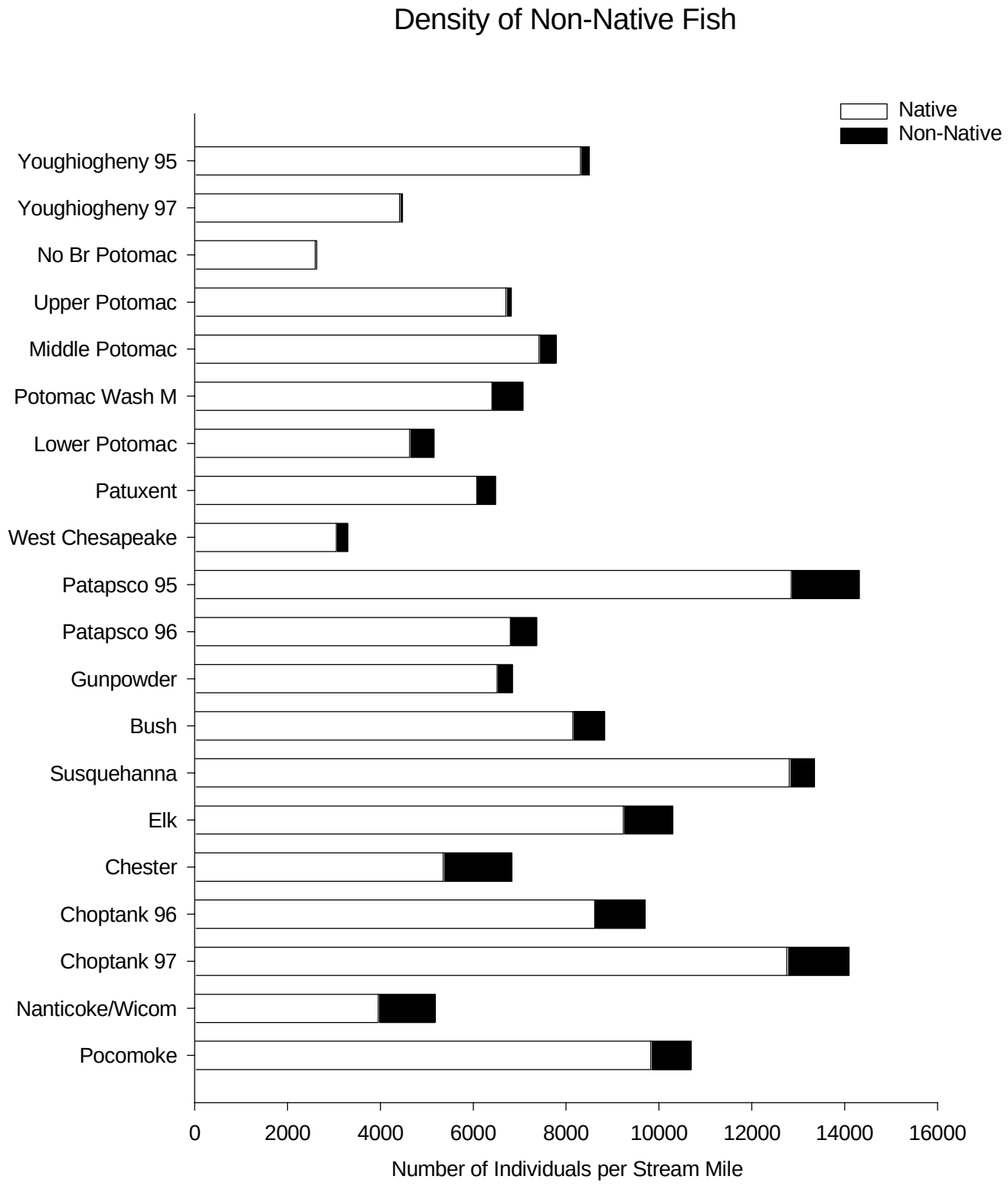

Figure 12-15. Density of native and non-native fish species for basins sampled in the 1995-1997 MBSS. Density estimates are adjusted for capture efficiency.

Although non-native fishes made up a fairly small percentage of the total fish fauna, these non-native species were widespread geographically. Statewide, 46% of first-to third-order streams contained non-native fish species. Thirteen of the 17 river basins contained non-native fish species in more than 50% of first- to third-order stream miles (Figure 12-16). The highest percentage of stream miles with non-native fish was in the eastern part of the State with basins in the Eastern Shore all exceeding 50%. In contrast, more western basins had the lowest percentages of stream miles with non-native fish: Youghiogheny 1995 (10%), Youghiogheny 1997 (30%), North Branch Potomac (17%), Upper Potomac (25%), and West Chesapeake (13%). Larger streams are more likely to have non-native fish than small streams (Figure 12-17). An estimated 86% of third-order and 68% of second-order streams had non-native fish species. In contrast, 46% of first-order stream had non-native fish.

Across all basins, a total of 19 non-native fish species were captured (Table 12-4). Note that different subsets of species are considered native to the Youghiogheny drainage versus the Chesapeake drainage. Although the Chester and Choptank basins contain some of the highest densities of non-native fish, these numbers result from the fewest number of species; only black crappie, bluegill, and largemouth bass were found. In contrast, six Maryland basins contained 10 or more non-native fish species: Upper Potomac (14), Middle Potomac (11), Potomac Washington Metro (10), Patuxent (9), Patapsco (12), and Susquehanna (10). Among the 19 non-native fish species in Maryland, seven are gamefish, and they included the ubiquitous (occurring in all 17 basins) bluegill, largemouth bass, and pumpkinseed.

12.6 NATURAL STREAM ECOSYSTEMS

The description of the distribution and abundance of aquatic ecosystems is more difficult than the characterization of species diversity, because we lack an effective classification of aquatic ecosystem types. Within the non-tidal stream ecosystem type itself, there is considerable natural variation in the composition of aquatic communities among stream orders and geographic areas. Other factors, such as local climate, soils, and historical events, also affect ecosystem diversity. This suite of factors also determines landscape diversity (the distribution and abundances of landscapes within a larger region) by influencing the dendritic network of streams in a river basin. Given these relationships, a rigorous assessment of aquatic diversity requires both a classification of ecosystem and landscape types and an analysis of their geographic pattern.

Recognizing that the Survey does not currently provide the information for such a rigorous analysis, several kinds of results can be used to identify streams and stream networks that are noteworthy examples of naturally functioning community or ecosystem types. In developing the provisional Index of Biotic of Integrity for fish (Roth et al. 1999), cluster analyses of the fish species compositions at each sample site identified major differences between the Highlands, Eastern Piedmont, and Coastal Plain regions of Maryland. Additional cluster analyses with additional MBSS data may reveal other regions or stream types that contain different characteristic communities of fish or other organisms. It is also possible that the common evolutionary and ecological history of stream ecosystems within a single river basin constitutes a unique ecosystem type. For the purposes of this report, MBSS data were used to identify (1) least disturbed or high-integrity streams (i.e., those rated as good for the fish IBI or benthic IBI) and (2) streams with only native fish species. These areas of high biological integrity and original species composition are, by definition, areas that function most naturally and contribute to biodiversity at the ecosystem and landscape levels.

12.6.1 High-Integrity Streams

The fish and benthic IBIs developed by the Survey are indicators of the degree to which human activities have altered natural conditions in streams based on deviation from minimally impaired reference sites. We recognize that these reference sites inevitably have some degree of anthropogenic influence (e.g., atmospheric deposition), but they serve as a useful means of designating an IBI score to denote "natural" communities likely to support original ecological and evolutionary processes. For the purposes of this analysis, natural streams are those that received a “good” IBI rating of at least 4.0 on a 1 to 5 point scale (see Chapter 5).

Of the 17 basins in Maryland, the Elk, Bush, and Lower Potomac were the only basins with more than one-third of stream miles in good condition based on the fish IBI (see Table 5-4 in Chapter 5). In contrast, less than 10% of the stream miles in the Nanticoke/Wicomico, Upper Potomac, and West Chesapeake were classified as good. The number of high integrity stream miles based on the fish IBI generally corresponded well with the physical habitat index, but did not correlate with the benthic IBI. Statewide, 20% of stream miles were rated good by the fish IBI, 11% were rated good by the benthic IBI, and 33% were rated good by the Physical Habitat Index. Only 21 sites sampled by the Survey were rated as good for all three indicators; 38 sites were rated as good by both the fish IBI and benthic IBI.

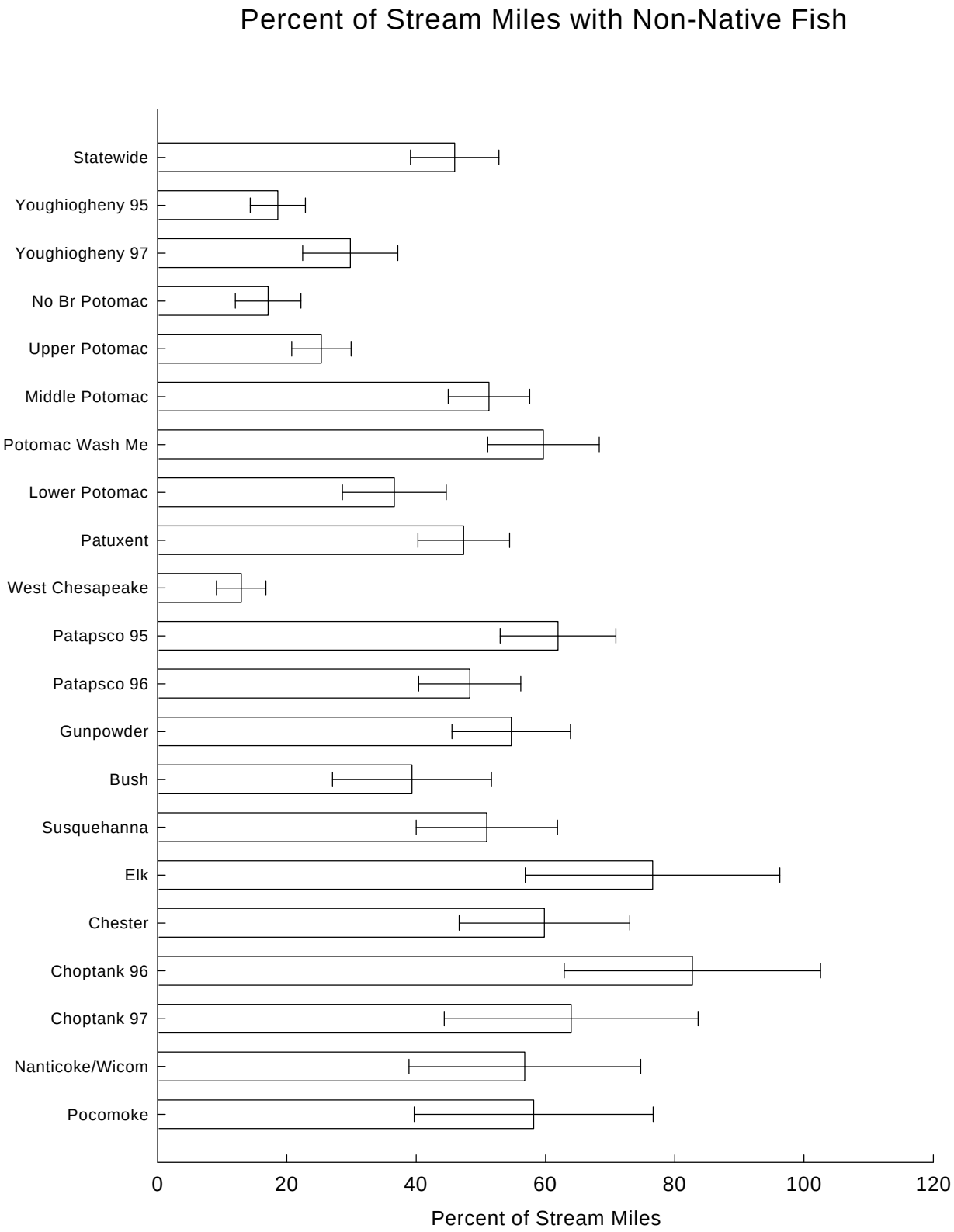

Figure 12-16. Density of non-native fish species for basins sampled in the 1996-1997 MBSS. Error bars represent ± 1 standard error

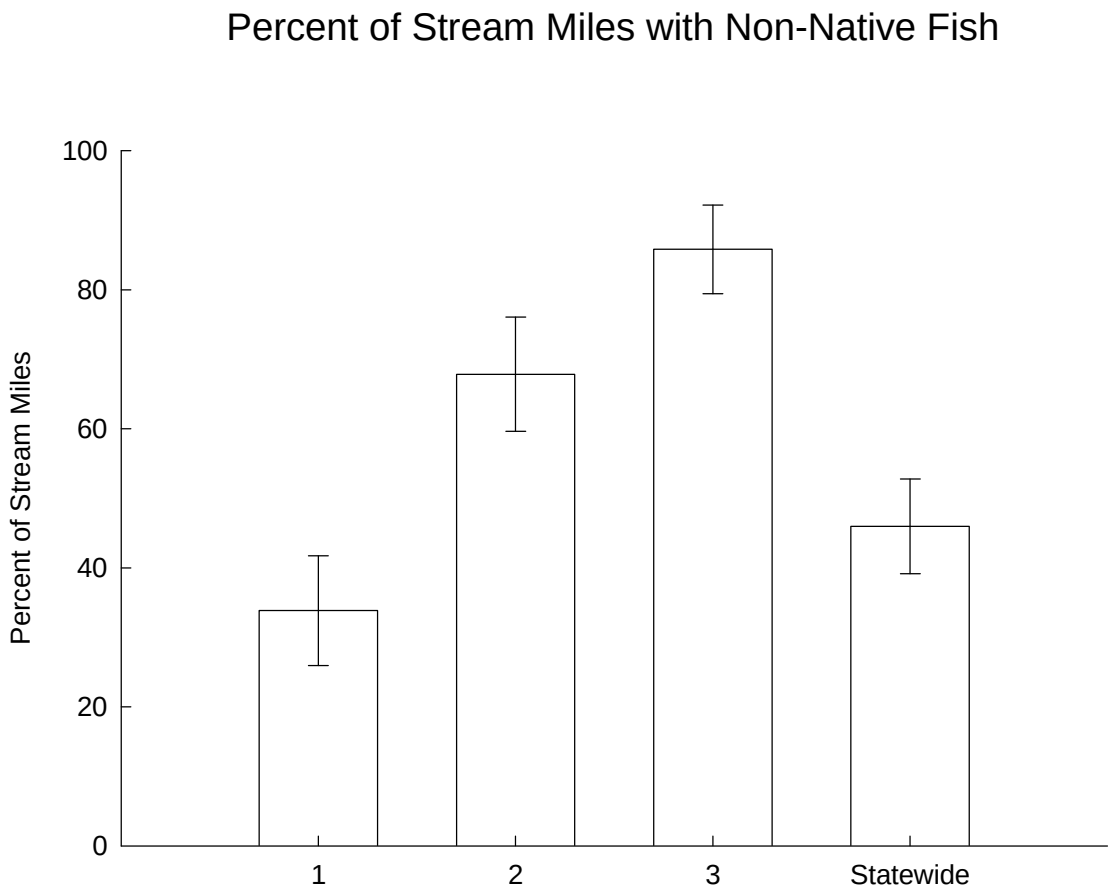

Figure 12-17. Percentage of stream miles with non-native fish species, by stream order, 1995-1997 MBSS. Error bars represent ± 1 standard error.

The 38 sites with high biological integrity were distributed among 10 river basins with nine in the Youghiogheny and eight in the Lower Potomac basins (Figure12-18). These sites likely represent some of the most natural stream ecosystem conditions in Maryland.

This approach to identifying natural stream ecosystems can be expanded to the landscape level by looking on a finer scale at those stream networks that have both multiple good sites and no poor sites (using the fish IBI, benthic IBI, physical habitat index, or any combination of indices) as candidates for harboring unimpaired ecological and evolutionary processes. Such sites could be the focus of landscape-scale conservation efforts. At the same time, conservation efforts may be targeted on the few good streams that persist among many poor streams, the good streams may be the last remaining example at a vanishing ecosystem type.

12.6.2 Native-Only Streams

High-integrity streams are even more likely to support natural ecosystem processes in the absence of non-native species. Non-native species can dramatically alter species compositions and ecosystem processes (Hunter 1996). It is important to note that non-native species occur at many of the 264 good fish IBI sites. In 13 of the 17 basins sampled, at least 67% of the good stream sites (fish IBI of 4.0 or greater) contained one or more non-native species. Of those basins with more than 3 good stream sites, only the Upper Potomac (0% non-natives) and Susquehanna (7%) were generally free of non-natives.

Stream sites with only native fish species are fairly evenly distributed across the State (Southerland et al. 1998, 1999). However, only 56 of the 905 streams sampled in the 1995-1997 MBSS have only native fish species and high biological integrity (based on fish IBI scores). Twenty of these streams are clustered in the far western part of Maryland, while the others are scattered mostly in the central part of the State. Therefore, these streams provide another potential focus for biodiversity conservation efforts.

Table 12-4. Basins in which non-native fish species occur for the 1995-1997 MBSS

Fish Species	Youghiogheny	North Branch Potomac	Upper Potomac	Middle Potomac	Potomac Washington Metro	Lower Potomac	Patuxent	West Chesapeake	Patapsco	Gunpowder	Bush	Susquehanna	Elk	Chester	Choptank	Nanticoke/Wicomico	Pocomoke
Chain pickerel	Y		N		N	N	N	N	N				N	N	N	N	N
Redfin pickerel	Y				N	N	N	N	N		N		N	N	N	N	N
Common carp		I	I	I	I	I			I		I	I	I				
Fathead minnow	I		I	I	I	I	I		I	I							
Goldfish			I		I	I		I	I		I						
Channel catfish			C	C			C					C					C
Brown trout	I	I	I	I	I		I		I	I		I	I				
Cutthroat trout		I	I						I								
Rainbow trout	I	I	I	I	I		I	I	I	I	I	I	I				
Black crappie			C			C	C	C	C					C	C	C	C
Bluegill	N	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Green sunfish	N	C	C	C	C	C	C	C	C	C	C	C		C			
Largemouth bass	N	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Longear sunfish			C	C						C							
Pumpkinseed	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Rock bass	N	C	C	C	C				C	C		C					
Smallmouth bass	N	C	C	C	C		C		C	C	C	C	C				
Banded darter												I					
Yellow perch	Y	N			N	N	N	N				N	N	N	N	N	N

Notes:
I = Introduced in both the Youghiogheny and Chesapeake drainage basins
C = Introduced to the Chesapeake drainage basin only
Y = Introduced to the Youghiogheny drainage basin only
N = Occurs as a native to that basin

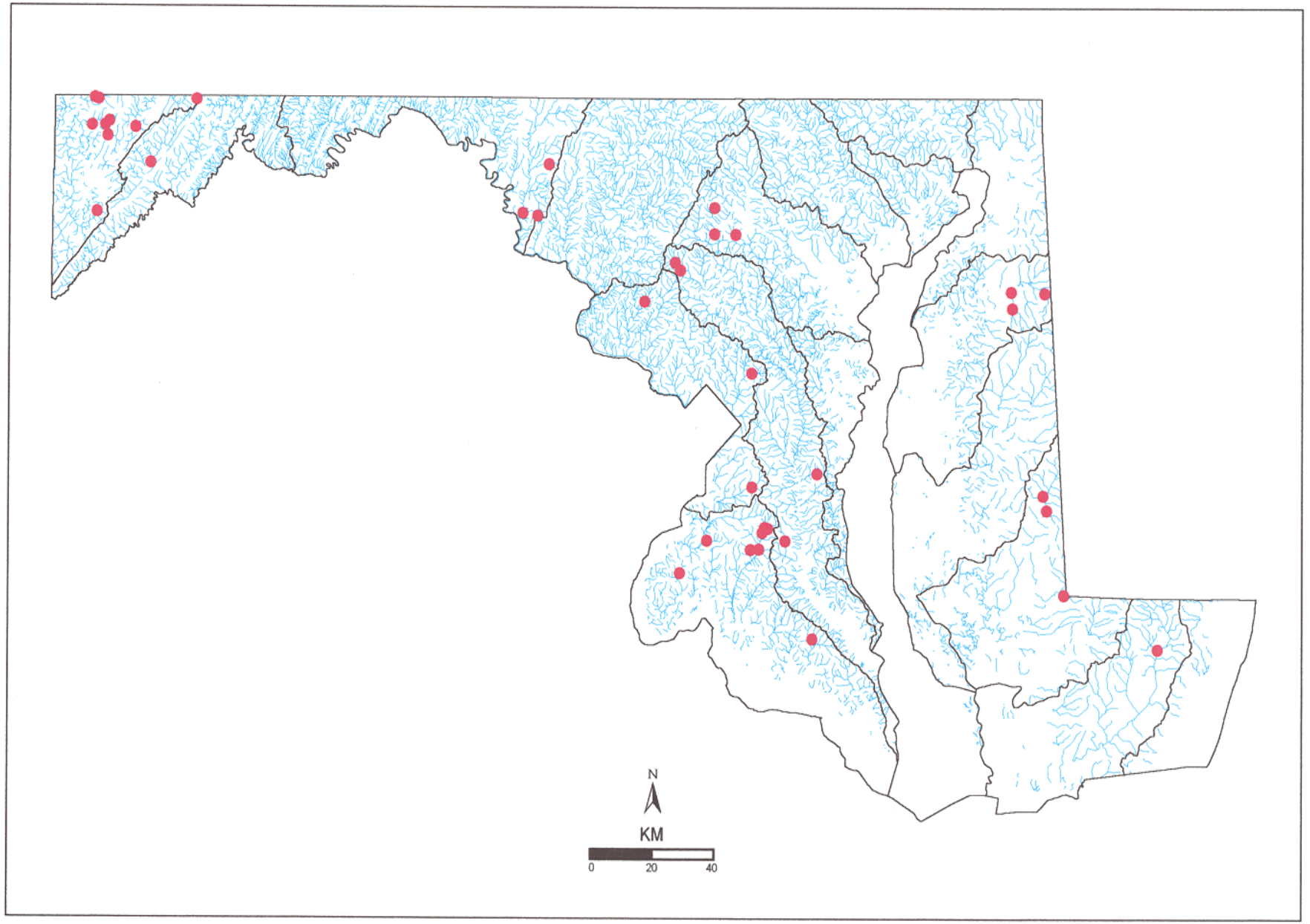

Figure 12-18. Sites that rated good (IBI scores ≥ 4.0) for both the fish and benthic Index of Biotic Integrity